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COGENERATION AND WASTE HEAT RECOVERY

MG-9996

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

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1.0 EXECUTIVE SUMMARY

1.1 This report was funded under the Manitoba/Canada Energy Agreement for the Development and Demonstration of Renewable Energy and Energy Conservation Technologies. The objective of this study is to assess the potential development of cogeneration and waste heat recovery in Manitoba industries and to estimate the cost of such development.

1.2 Cogeneration is defined as a system for the simultaneous production of electricity and useful heat for industrial processes from the same fuel source. This system converts fuel to electricity and useful heat at very high efficiencies, permitting small cogeneration systems to compete with large utility operated, steam condensing systems. There are four practical technologies or cycles used in cogeneration:

(a) Steam turbine or Rankine Cycle
(b) Gas turbine or Brayton Cycle
(c) Diesel-electric system
(d) Organic Rankine Cycle

For all practical purposes, only steam turbine and gas turbine technologies are applicable to Manitoba industries. Diesel electric systems are limited in producing the good quality steam required by industry, and the Organic Rankine Cycle is still in the developmental stages.

1.3 The information for this study was obtained through a mailed survey and plant visits by qualified engineers. The survey sample consisted of 88 establishments, of which 46 responded. This is a high response level for this type of a survey, especially as the respondents were mainly from energy intensive industries. The responding establishments represent about 75% of the province's fuel purchases.

The potential for cogeneration in Manitoba was established with information obtained from the plant visits. The number of establishments in Manitoba capable of technically cogenerating is 13.

The total electricity generating capacity of this potential is as follows:

Steam Turbine	44 MW
Gas Turbine	168 MW
	212 MW

1.0 RÉSUMÉ ADMINISTRATIF

1.1 Ce rapport a été financé par l'Entente Canada-Manitoba pour le développement et la démonstration des énergies renouvelables et la technologie des économies d'énergie. Le but de cette étude est d'évaluer les possibilités de cogénération et de récupération de la chaleur perdue dans les industries manitobaines et d'évaluer le coût de ces systèmes.

1.2 La cogénération est la production simultanée, à partie de la même source de combustion, d'électricité et de chaleur utile aux processus industriels. Le combustible est transformé en électricité et en chaleur utile avec une très grande efficacité, ce qui permet à de petits systèmes de cogénération de se mesurer aux grands systèmes de condensation de la vapeur des compagnies de services publics. Il y a quatre type de technologie ou cycles utilisables pour la cogénération:

a) turbine à vapeur ou cycle Rankine
b) turbine à gaz ou cycle Brayton
c) système diesel-électrique
d) cycle Rankine organique

À toutes fins pratiques, seules les turbines à gaz ou à vapeur sont utilisables dans l'industrie manitobaine. Les systèmes diesel-électriques ne sont pas tout à fait en mesure de produire la vapeur de bonne qualité dont a besoin l'industrie, et le cycle Rankine organique en est encore au stade expérimental.

1.3 Les renseignements pour cette étude ont été recueillis au moyen d'une enquête menée par courrier et des visites à des usines faites par des ingénieurs qualifiés. 88 établissements avaient été sélectionnés pour le sondage et 46 y ont répondu. Cela représente un pourcentage élevé pour ce genre d'enquête, d'autant plus que les réponses venaient surtout de compagnies grandes consommatrices d'énergie. Les établissements qui ont participé au sondage représentent 75% des achats provinciaux de combustible.

Les possibilités de cogénération au Manitoba ont été établies à la suite des visites aux usines. Dans la province, 13 établissements sont techniquement capables d'utiliser la cogénération.

1.4 The capital cost of developing this potential in Manitoba is estimated at $91,312,000 with a payback period of 36.97 years. At this payback, cogeneration is not economical in Manitoba. The high payback period for this development is due mainly to the low cost of electricity from Manitoba Hydro with which cogeneration must compete. This price is at $0.0165/kWh. If the Hydro rate were to increase to $0.026/kWh, the payback would be less than 5 years.

1.5 Almost all industries in Manitoba reject heat from their industrial processes and buildings. If some of this wasted heat could be recovered and re-used, the purchases of fuel would substantially decline, saving large sums of money.

1.6 In Manitoba there are 684 industrial establishments consuming about 33×10^6 GJ/yr of fuel. It is estimated that about 19.5×10^6 GJ/yr is rejected, of which 3.2×10^6 GJ/ur can be recovered. The capital cost of this development would be $31 million with a payback period of 4.4 years. This estimate was based on information received from the survey and on our calculations.

1.7 There are several types of heat recovery equipment on the market which can be applied to Manitoba industries. Some of it has been used in the process industries for many years, and some is relatively new. Additional effort is needed to make industry aware of the application of this equipment for heat recovery purposes, its potential, its availability and its cost.

1.8 At this time, industries are not investing in waste heat recovery equipment mainly because of an unawareness of its cost effectiveness in many applications. In order to encourage more activity in the area of conservation of energy through waste heat recovery, it is recommended that four projects be undertaken to demonstrate the most cost effective technologies.

La capacité de production d'électricité que ce potentiel représente est la suivante:

Turbine à vapeur	44MW
Turbine à gaz	168MW
Total	212MW

1.4 L'utilisation de ce potentiel au Manitoba demanderait une immobilisation de 91 312 000$, amortissable en 36.97 ans. Avec une telle période d'amortissement, la cogénération n'est pas viable économiquement au Manitoba. L'amortissement est très long en raison du bas prix de l'électricité fournie par Hydro Manitoba, qui coûte 0.0165$/kWh. Si le prix du kWh passe à 0.026$ l'immobilisation serait amortie en moins de 5 ans.

1.5 Presque toutes les industries manitobaines rejètent la chaleur produite dans leurs bâtiments et au cours du processus de fabrication. Si l'on récupérait et réutilisait une partie de cette chaleur, les achats de combustibles diminueraient considérablement et on réaliserait des économies importantes.

1.6 Il y a au Manitoba 684 établissements industriels, lesquels consomment environ 33×10^6 GJ/an, dont 3.2×10^6 GJ/an pourraient être récupérés. L'aménagement nécessaire exigerait des immobilisations de 31 millions de dollars, et la période d'amortissement serait de 4.4 ans. Cette évaluation est fondée sur les renseignements recueillis lors de l'enquête et sur nos propres calculs.

1.7 On trouve sur le marché plusieurs types de systèmes de récupération de la chaleur utilisables au Manitoba. Certains sont en usage depuis plusieurs années dans les industries de traitement, d'autres sont relativement nouveaux. Il faut faire un plus grand effort d'information auprès des établissements industriels concernant l'utilisation de ces systèmes pour la récupération de la chaleur, leur potentiel, leur disponibilité et leur coût.

1.8 Actuellement, si l'industrie n'investit pas dans le matériel de récupération de la chaleur, c'est surtout parce qu'elle connait mal son efficacité économique dans de nombreuses applications. Afin d'encourager un intérêt actif dans le domaine des économies d'énergie par la récupération de la chaleur, nous recommandons d'entreprendre quatre projets de démonstration de la technologie la plus efficace.

2.0 INTRODUCTION

Concerns over energy supplies and the price of energy expressed by both suppliers and users in the past few years have prompted many investigators to direct their attention to the efficiency with which energy is being used in producing goods and services. This is especially true for the industrial segment of our economy where energy is one of the significant input factors of production. [1]

In 1980, Manitoba industries consumed about 50×10^6 GJ of various types of energy to light and heat factory space, to heat, melt, mould and finish products, to move materials, gases and liquids, and to operate computers and communication systems. Therefore, energy is vital to the competitive health of Manitoba's industry and to the general welfare of the nation.

Industrial development depends to a significant extent on the price of energy and its availability. Since the price of most fuels is determined outside of Manitoba, industry is attempting to hold down the total cost of energy by using it at higher efficiencies.

This increasing of efficiency in energy use is being accomplished by many methods, some of which are:

1. General housekeeping and maintenance;
2. Use of new materials or improved and more efficient processes and equipment;
3. Recycling of materials;
4. Modification of existing equipment;
5. Reduction of energy losses in boilers, ovens, furnaces, pipelines, etc.;
6. Use of Cogeneration;
7. Recovery of waste heat from industrial processes and effective utilization of it to reduce the purchase of fuels.

Various programs have been announced by both the Manitoba government and the Federal government to assist industry in their attempts to save energy through indentification of the conservation potential, energy audit programs with the Energy Bus, financial assistance for renewable energy utilization, risk capital for new energy saving technologies, etc. As a continuation of these activities, this study was authorized by the governments of Canada and Manitoba to establish the potential for Cogeneration and Waste Heat Recovery in Manitoba.

3.0 SCOPE AND OBJECTIVES

The purpose of this study is to:

a) Perform a technical review of cogeneration and waste heat utilization, and analyze the factors affecting the development of these technologies,

b) Determine the potential for industrial cogeneration and waste heat utilization in Manitoba,

c) Identify the opportunities for applying these technologies in industry,

d) Estimate the capital cost of developing cogeneration and utilizing waste heat,

e) Identify policy considerations for the government of Manitoba,

f) Recommend specific sites for more detailed study, and/or demonstration projects,

g) Together with the management of these sites, develop proposals to the Manitoba/Canada Energy Agreement program.

The above work was accomplished through:

a) A market survey of Manitoba's industry,

b) Follow up visits of potential sites of applications,

c) Specifications and cost estimates provided by equipment suppliers,

d) Technical and economic analyses of cogeneration and waste heat recovery at each site, and

e) Review of institutional factors impeding the development of these technologies.

4.0 METHOD

Manitoba has about 690 industrial establishments which are divided into Standard Industrial classes. A list of all these establishments was obtained from Scott's Industrial Directory for Manitoba. From this list, a representative sample of industries from each classification was selected. In order to investigate as many of the large users of energy as possible, it was decided to include the two largest establishments from each classification, while selecting the rest randomly. A total sample of 88 establishments was selected. (See Appendix A)

A simple one-page questionnaire was sent to this list of companies to determine the energy use levels and to obtain some indication of waste heat streams with their temperature and flow characteristics. In addition to the questionnaire, 16 establishments were visited by our qualified engineers to review their audit and to advise plant personnel on techniques of waste heat recovery, availability of suitable equipment, estimates of capital costs, and government assistance programs for industry. In total, 46 questionnaires were received as a response to the survey. Of these, 12 were eliminated from the study, since they were only partially completed and represented small, low energy use establishments. The remaining 34 were complete, and sufficient information was provided to calculate pay-back periods.

5.0 COGENERATION

5.1 Technical Review

Cogeneration is an efficient method of producing electricity. Industrial cogeneration has been practiced in Manitoba since the turn of the century. Its development, however, ceased after the Second World War as a result of the abundant availability of inexpensive fuels, and the shortage of trained labour. The economies of scale of large power systems and the harnessing of huge hydraulic resources of the Nelson and other rivers gradually reduced the financial attractiveness of cogeneration. Presently, however, this economic trend has been reversed through the expected increase in electricity costs, decreased fuel availability, conservation awareness, and technological advances. Cogeneration is once again receiving its due attention.[2,3]

It has been recognized for some time that electricity and steam can be generated together in the same power plant more efficiently than if they are generated separately in different power plants. This simultaneous production of electricity and thermal energy (steam, hot liquids, hot gases) is referred to as cogeneration.

There are four common technologies used in cogeneration. The most widely used industrial electricity generating cycle is the Rankine Cycle which uses high pressure steam produced in boilers to drive a steam turbine. The exhaust steam from this turbine can be used to heat processes or factory space. (See Figure 5.1) This cycle is sometimes referred to as a 'Bottoming Cycle'.

A second technology is the Diesel generating unit. These have been used extensively in the Canadian north and in areas of resource development such as mines and oilfields, as well as in transportation. A diesel engine turns a generator to produce electricity, and the heat recovered from the engine cooling system (radiator), together with the energy in the exhaust gas are used to heat space in many northern communities. No application of this technology was detected in Manitoba. Several of these units are used as emergency generation plants in hospitals, mines and the petro-chemical industries, but the expensive diesel fuel, and low overall cycle efficiency precludes their use as a primary source of electricity.

The third and newest technology is based on the Brayton Cycle which uses the gas turbine similar to that of jet engines in aviation. In this cycle the fuel, either natural gas or other petroleum fuels, is burned in the turbine to produce mechanical power which turns a generator. The high temperature exhaust gases (450°C) are fed into a waste heat recovery boiler to produce steam, or are used as hot combustion air in the existing boiler. The ability to use this hot, clean gas in existing boilers gives this technology a competitive edge over the other two cycles. (See Figure 5.2)

If the Brayton Cycle is considered, then the potential for cogeneration is expanded considerably. In Ontario, the Rankine Cycle potential is estimated to be only 540 MW, while with the Brayton Cycle it can be as high as 5,200 MW. Similarly in Manitoba, the Rankine Cycle potential is 44 MW, while with the turbine it increases to 212 MW.

Electricity can also be generated in industry from waste heat recovered from high temperature direct-fired combustion processes found in metal producing plants and non-metallic mineral factories. In a case where fossil fuel is used to fire an industrial process and the waste energy is used to generate electricity, this is referred to as a "bottoming cycle". In a more advanced cogeneration technology, both topping and bottoming cycles are used to obtain a cycle of high efficiency.

An attractive feature of bottoming plants is the generation of electric power without direct fuel consumption. It is generally recognized that a significant amount of thermal energy is released by industry to the atmosphere at sufficiently high temperatures to suit cogeneration, using bottoming cycles. The largest potential for bottom cycle heat recovery exists in the Primary Metals industry and the Non-metallic Minerals industry, where heat is rejected at high temperatures (800-1500°F) from furnaces melting metals, roasting ores and reheating steel.

From the thermodynamic standpoint, the exploitation of this wasted heat to produce electricity results in a high overall efficiency of energy use. This efficiency depends on the ratio of waste heat that can be successfully turned into useful work. For the established technologies of steam plants and Organic Rankine Cycle (ORC) plants, this ratio is

the function of the thermodynamic characteristics of the working fluid itself. These characteristics of an Organic (Flourinol 85) Rankine Cycle are shown in Figure 5-3.

At about 1,000°F the ORC with F-85 performs at a level similar to steam, and below 500°F, a fluid other than F-85 would provide better results. Sunstrand Energy Systems in the United States and Borsig in West Germany produce ORC engines capable of generating about 600-6,000 kW of energy from waste heat at higher than 600°F. For single units with inlet gas temperatures of 800°F, a mass flow of 75,000 lbs/hr is required to generate 500 kW of electricity.

With Organic Rankine Cycle type of engines, the cogeneration potential can reach 6 MW of electricity from the recovery of industrial exhaust gases, which are estaimated at 120×10^6 BTU/year. However, at this time, this technology is costly, and is still in the experimental stages. Only demonstration units for a total of 2-3 MW are foreseen in the next 10 years. Therefore, the cogeneration potential from this technology is considered to be negligible.

5.2 Fuel Considerations for a Cogeneration System

In order to produce electricity in a topping cogeneration station, industries would have to purchase additional fuel. A steam turbine station can use almost any fuel, therefore it is economics which will determine the choice of its fuel. In the case of a gas turbine station, it is limited to natural gas, by-product gas and light distillates.

The National Energy Board estimates that all fuels will continue to be available in Canada for at least the next ten years.[4] Beyond that period the availability of crude oil will depend on exploration and development successes in the off-shore and frontier areas of Canada. It is also apparent that the world is using up known reserves of economically accessible oil faster than new supplies are being found. Canada's commitment to the International Energy Agency to reduce its crude oil consumption by 2.5% per year precludes the use of oil-based products for cogeneration. However, natural gas is available in western and central Canada, and most of the existing large boilers are fired by this fuel.

Over the long term, coal, municipal waste, and forest by-products are expected to become increasingly important fuel sources, and they are all suitable for cogeneration. Municipal waste and forest biomass should be utilized wherever it exists. Sawdust in Pulp and Paper mills, for example, can be turned from an environmental problem to fuel and energy by burning it for cogeneration. The same applies to municipal solid waste. The major obstacle to these two fuel sources is their limited supply at locations where it can be utilized.

Canada's recoverable coal reserves are enormous as an energy source when compared with the remaining recoverable reserves of conventional crude oil and natural gas. A return to coal firing is generally predicted in North America, and in fact, in the United States, this conversion is dictated by legislation for units of 100,000 lbs/hr and larger. In Canada, the Federal government is also encouraging the use of coal, especially on the east coast.

There are only two known industrial establishments in Manitoba which are using coal as their main fuel, and their total purchases in 1980 were about 152,000 tons/yr. Coal is delivered to these plants by train.

When considering the use of coal, industries must overcome the additional costs associated with it, which include, besides transportation costs, efficiency considerations and environmental costs. Conversion from oil or gas to coal is not a simple matter. Coal burning boilers are about three times the size of oil fired boilers. Space is also required for coal piles, coal bunkers, coal handling equipment, ash handling equipment, dust collectors, electrostatic precipitators, etc. Furthermore, this larger equipment is also more expensive. A 500,000 lbs/hr boiler costs about 2.75 times that of an oil burning unit of a similar capacity. Nevertheless, the cost of coal itself favours its use and coal prices are likely to rise at a much lower rate than oil or natural gas. By 1990 the difference may be great enough to encourage some large industrial establishments to consider this fuel as their prime source of energy. In addition, the development of fluidized bed combustion will permit the burning of coal with lower pollution. More generally, fluidized bed combustors offer the flexibility of allowing the use of any low grade fuel for the operation of a gas turbine, including municipal waste.

The development of this technology in Manitoba would permit the utilization of low quality coal and municipal waste by industry and commerce within the air quality requirements of provincial environmental laws.

Recent re-evaluation of the known resources of natural gas in western and northern Canada, and optimistic predictions of substantial discoveries of gas on the Sable Islands off the coast of Nova Scotia, have prompted the Federal government to initiate programs which would encourage the use of gas for industrial processes, among them, cogeneration. The National Energy Board, after lengthy hearings, has concluded that: "...the total demand east of Alberta, including authorized exports, can be met until 1992, assuming no additional restrictions resulting from the Alberta protection procedure."

At present, there are abundant amounts of natural gas in Manitoba coming from Alberta. However, its increasing price does not permit its use for the production of electricity in Manitoba. In fact, its price escalation is encouraging industry to review their energy equipment for efficiency and waste heat recovery.

Municipal solid waste can be considered as a source of energy. Most of this energy could be converted in high pressure boilers, which could supply a steam turbine to produce electricity. In some cases, where the steam load is not within a transmission distance of the waste-burning plant, only electricity can be produced, as is the case of the SWARU plant in Hamilton, Ontario.

Evaluation of waste conversion for the City of Winnipeg has been undertaken in the past several years and its conclusion favoured establishing an incinerator with a heat recovery system. The quality of heat is adequate to produce steam for cogeneration. Other municipalties have sufficient volume of waste to consider incineration. This potential cogeneration, using municipal waste as fuel, can only be developed if the economics of it prove feasible, and if a sound ownership, management and operational structure is in place by the target date of the announced program.

5.3 Technical Potential and Opportunities

A study conducted for the Department of Energy, Mines and Resources, Ottawa [3] in 1979 set the potential for cogeneration in Manitoba using the Rankine Cycle at 44 MW as follows:

TABLE 5.2

Cogeneration Technical Potential by Site - Manitoba
Steam Turbine

Site Code	Technical Potential MW	Existing Capacity MW	Fuel
42	3.7	-	Natural Gas
29	18.4	9.4	Oil/Wood
27	5.0	1.9	Natural Gas
28	3.6	-	Oil
16	7.9	-	Coal/Wood
32	5.4	-	Oil/gas/refinery gas
	44.0	10.3	

TABLE 5.3

Technical Potential by Site

Site Code	Steam Turbine	Gas Turbine	Total
42	3.7	16	19.7
29	18.4	50	68.4
27	5.0	12	17.0
28	3.6	10	13.6
16	7.9	22	29.9
32	5.4	25	30.4
8	---	15	15
9	---	3	3
14	---	5	5
17	---	4	4
26	---	2	2
31	---	2	2
39	---	2	2
Total	44.0	168	212.0

Companies responding to the questionnaire have identified their steam and hot gases requirements which can be used to determine the technical potential of cogeneration. Table 5.3 summarizes the total technical potential when both cogeneration cycles are used. By adding the gas turbine, the potential rises to 168 MW under the present heat energy requirements. In most of the establishments where steam requirements were continuous throughout the year, the flow of 5 GJ/hr of steam or hot gas was sufficient to justify a 1 MW gas turbine. In most cases the flow in summer, the low flow period, was more than 10 GJ/hr. With the gas turbine, the steam conditions are not a determining factor. The exhaust gases from the turbine could be used to produce any desired steam condition, gas or air heating requirement, or hot water. Therefore, the cogeneration potential with gas turbines is high wherever there is a need for a continuous heating application. The majority of these applications are for pre-

Figure 5.1

Comparison of Utility Power Plant and Cogeneration Power Cycles

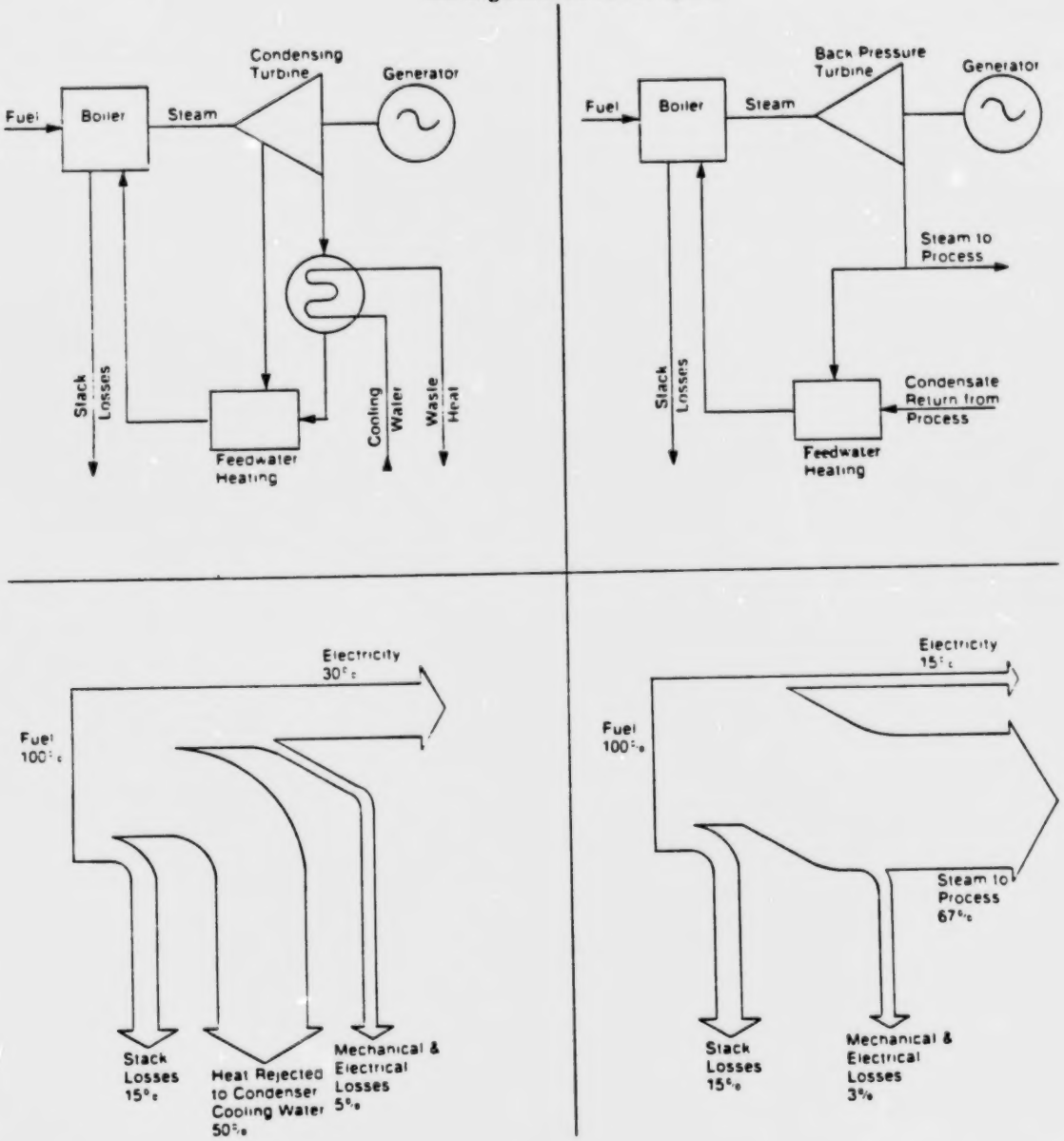


Figure 5.2

Gas Turbine Cogeneration Cycle

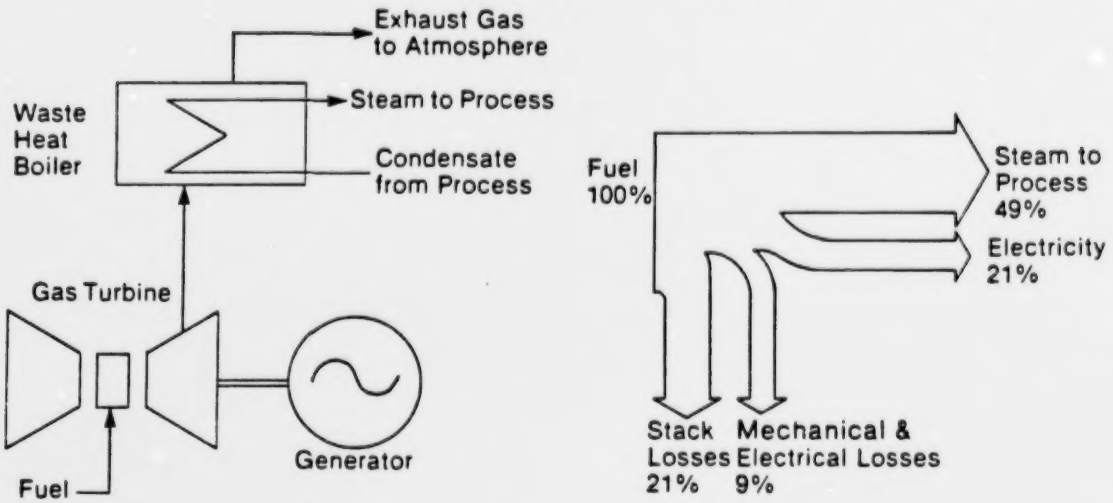
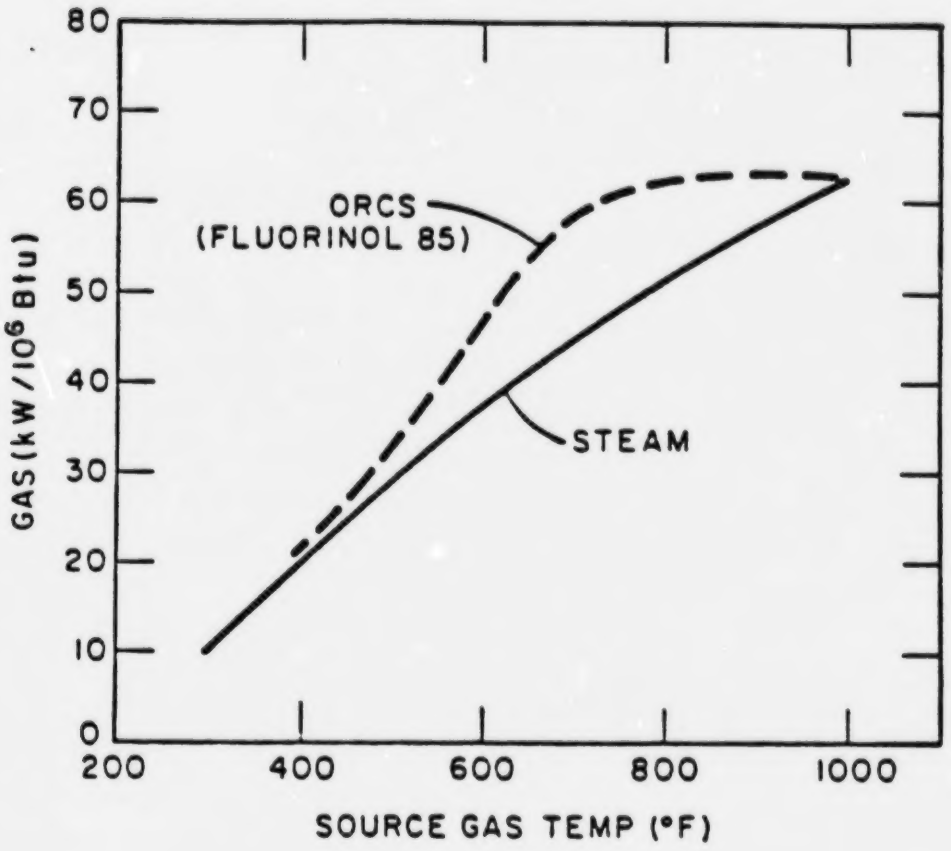


Figure 5.3



ASSUMPTIONS: $T(GAS)_{in} - T(STEAM)_{out} = 100^{\circ}F$

PINCH POINT = $40^{\circ}F$

OVERALL STEAM TURBINE-GENERATOR η = 68%

Maximum Power Potential for Bottoming Plants

heating of combustion air for boilers. In two establishments, hot gases from the turbine exhaust are used to preheat combustion air for steel furnaces.

Although the technical potential can be as high as 212 MW, the economic potential is determined by the cost of fuel, electricity rates, capital cost and load factor.

5.4 Estimate of Capital Cost

The two largest components of a cogeneration station are the boiler and the turbine-generator set, representing about 50% of the total installed costs. Of these two items, the turbine-generator is more expensive. The simple back-pressure steam turbine costs are between $315/kW and $510/kW depending on the size, as shown in Figure 5.4. An extraction turbine costs about 20% more than the back-pressure turbine. Gas turbines are less expensive than steam turbines for sizes larger than 5 MW, and about the same price for smaller sizes. Therefore, the total cost of a gas turbine station of a given size is usually less than it is for a steam turbine. If we assume that the cost of electricity production is incremental to the steam plant, the cost of the boilers would be charged against the steam production. Only the incremental cost of providing higher pressure boilers should be credited to the capital cost of producing steam to turn steam turbines for electricity production. In the case of gas turbines, the waste heat recovery boilers at the process pressure required cost about the same as low pressure fired boilers, and in this case, the incremental cost of steam production to the cogeneration station would be zero. Therefore, for a new station, the incremental cost of steam production allocated to the cogeneration station is very low. (See Figures 5.5, 5.6)

TABLE 5.4

Summary of Cogeneration Financial Data

	Potential Cogeneration MW	Capital Cost '000 $	Operating Cost '000 $	Saving '000 $	Pay-back yrs.
Steam	44	30,222	4,983	441	68.5
Gas	168	61,090	20,180	2028	30.12
Total	212	91,312	25,113	2469	36.97

Table 5.4 summarizes the financial data relating to the development of cogeneration in Manitoba. A detailed calculation for this table can be found in Appendix C. The total capital expenditure to develop 212 MW of electrical capacity is about $91,212,000. The pay-back period for this investment is about 37 years. However, the return on investment for cogeneration is very sensitive to the cost of fuel and electrical rates from Manitoba Hydro. Presently, the average cost of electricity in Manitoba to large industrial establishments is $0.0165/kWh. If this rate were to rise to the Ontario Hydro or B.C. Hydro level of $0.026/kWh, then the pay-back would be 4.86 years. At this pay-back most of the industrial establishments would be interested in developing their cogeneration potential, especially with gas turbines. The pay-back for cogeneration with gas turbines at $0.026/kWh would be only 4.15 years.

Figure 5.4

Turbine-Generator Set Costs
for Estimating Purposes

(1981)

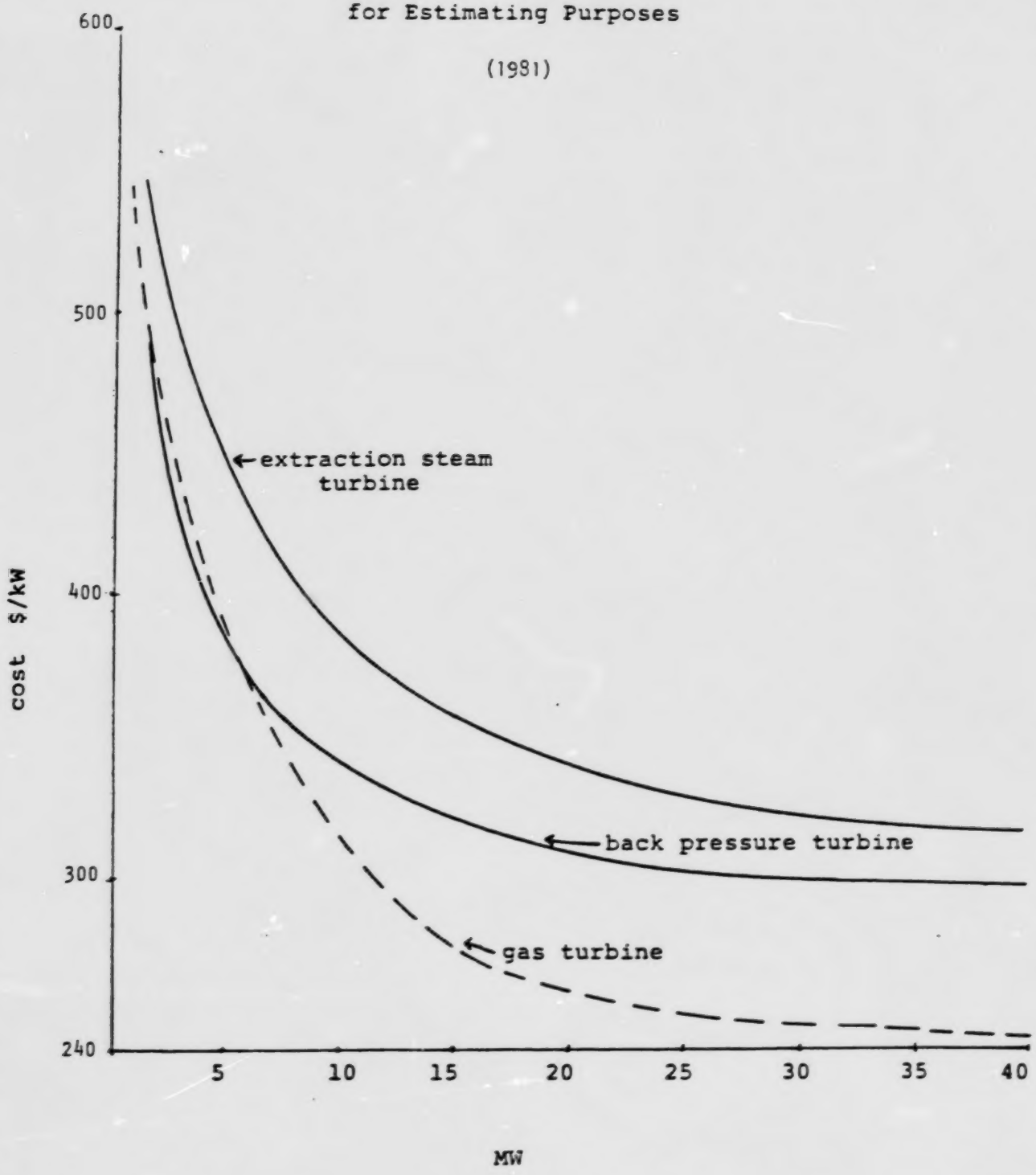


Figure 5.5

Boiler Costs

for Estimating Purposes

(1981)

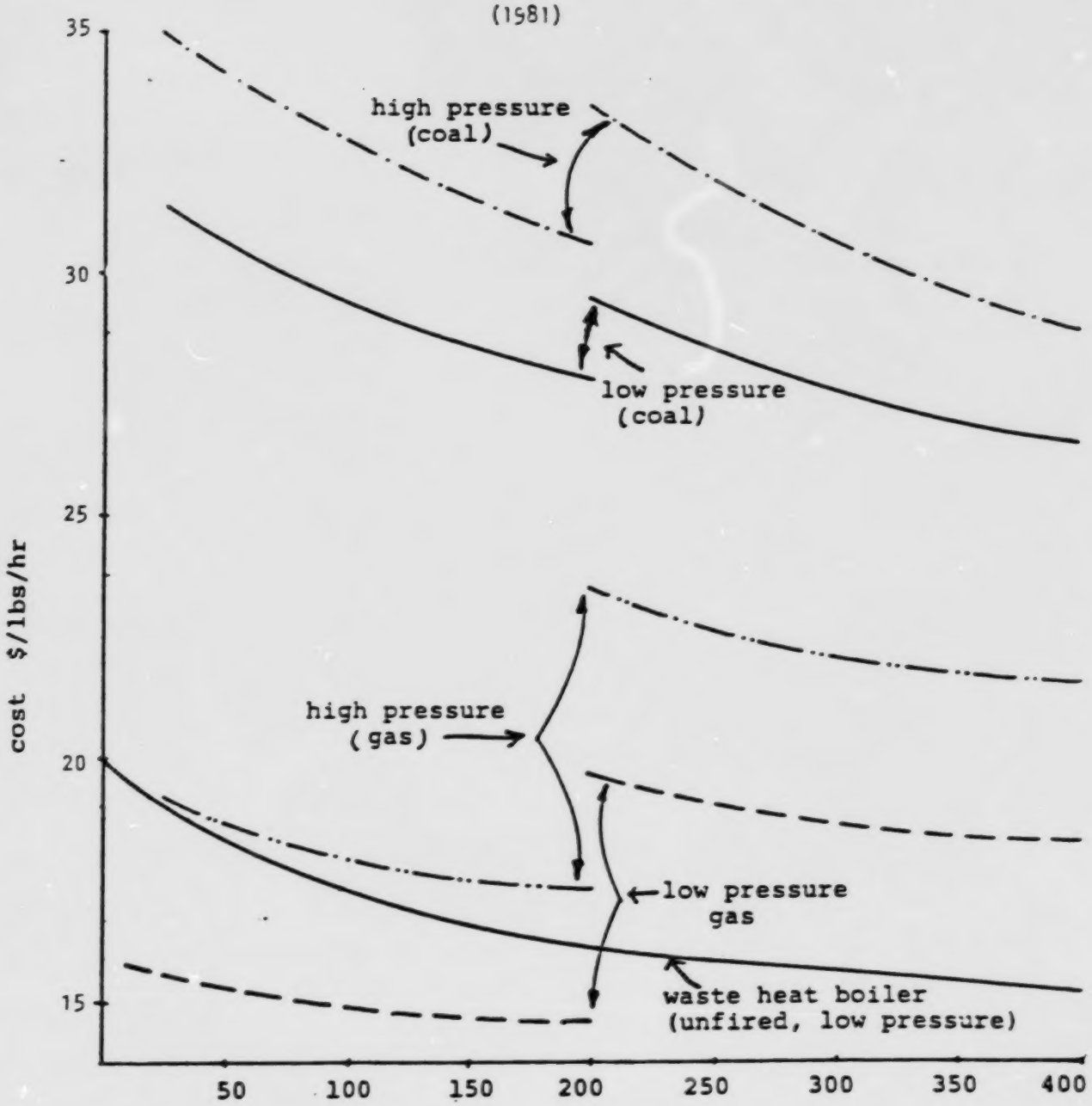
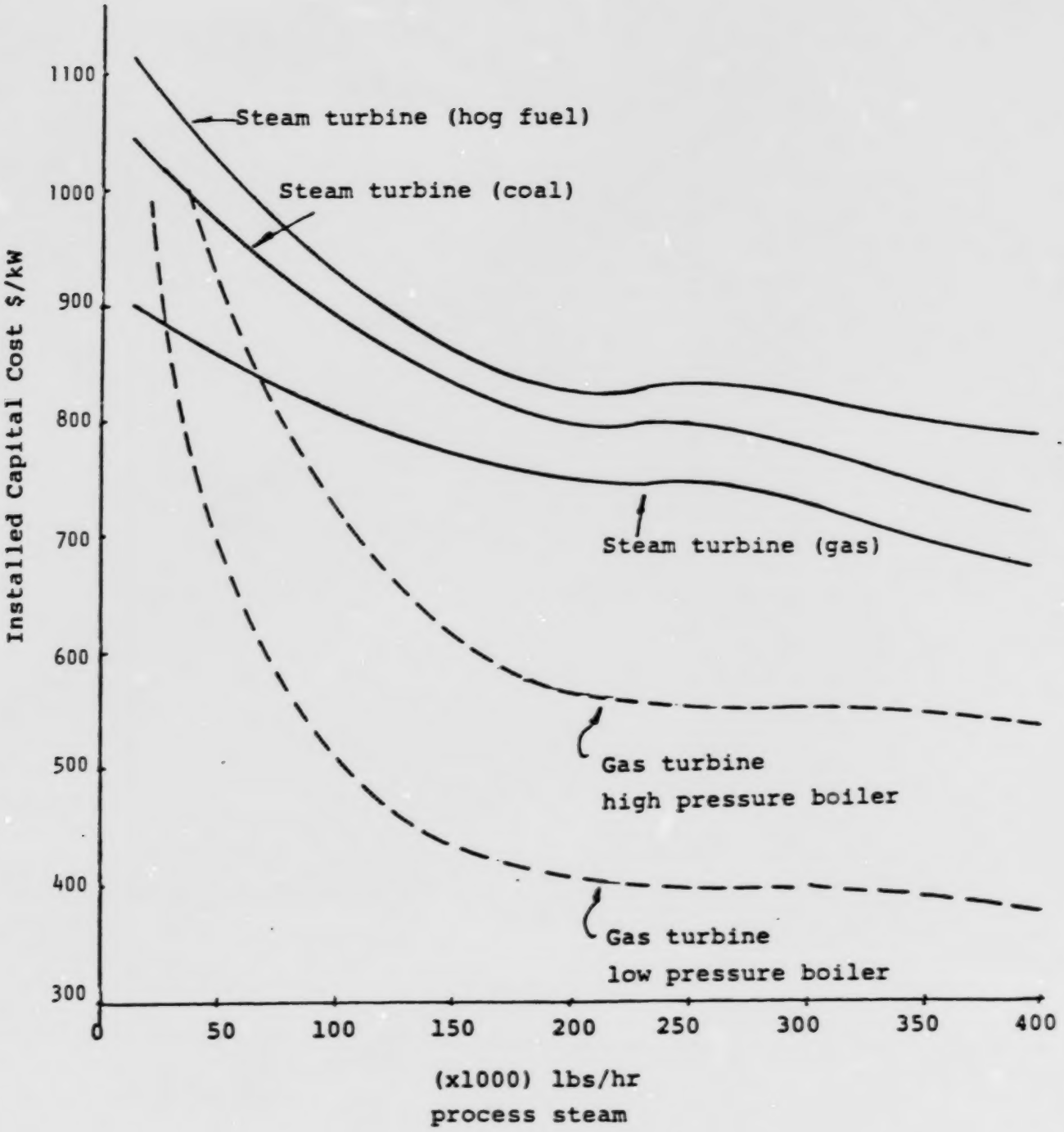


Figure 5.6

Incremental Cost
of
Cogeneration Stations

(1981)



6.0 WASTE HEAT RECOVERY

6.1 Technical Review

In the on-going search for energy conservation, industrial and commercial establishments are looking to squeeze more useful energy out of their purchased fuels. They are increasing the efficiency of their energy generating equipment through better control and technical design, and through recovery of energy from the existing waste heat streams.

Waste heat recovery offers the greatest potential for manufacturing plants to reduce their consumption of purchased energy. Waste heat is energy which is rejected into the atmosphere by thermal process. It can be in the form of hot liquids or gases, ranging in temperature from 80°F to 1500°F. It is rejected by refrigeration systems, cooling towers, furnaces, process ovens, dryers, condensers and boilers. Although the energy is there, its ability to do useful work is dependent on its quantity, quality, and match to process requirements.

Energy quantity is related to flow, and is measured in terms of BTU's or Joules, depending on which language you speak. Energy quality is more or less a function of the absolute temperature of the waste heat stream. Therefore, the terms quality and temperature can be used interchangeably.

In order to recover energy, there are two types of heat transfer equipment used. These can be classified as passive and active devices. Passive devices are heat exchangers which rely on temperature gradient for heat transfer. In this case, the quality of energy must be greater in the source of heat than in the application. However, there are many potential applications for heat recovery in the manufacturing industry where the reverse is true. The temperature of the waste stream is often cooler than that of the energy application site. This indicates that an active device such as a heat pump must be used for energy exchange.

TABLE 6.1

FUEL CONSUMPTION IN MANUFACTURING

MANITOBA

1000 GJ

Industry	Establishments	Fuel Consumed	%
Food & Beverage	135	5795.2	17.5
Rubber and Plastics	20	45.2	.1
Leather	8	149.0	.4
Textiles	24	34.2	.1
Knitting Mills	3	21.0	.1
Clothing	63	148.4	.4
Wood Products	39	136.8	.4
Furniture	34	141.5	.4
Paper & Allied Products	20	6996.0	21.1
Printing	54	182.9	.6
Primary Metals	12	4448.2	13.6
Metal Fabricating	70	706.4	2.1
Machinery	30	603.3	1.8
Transport Equipment	26	542.8	1.6
Non-Metallic Minerals	22	6275.0	18.9
Petroleum Products	5	4862.0	14.7
Chemical Products	25	3003.4	6.0
Misc. Industries	27	53.1	.2
	684	33146.2	100.0

In commerce, the main sources of waste heat are boiler stack gases and ventilation air. In industry, there are many sources, related both to the space heating of plants and factories and to industrial processes.

A recent study on Waste Heat Recovery Potential by the Department of Energy, Mines and Resources[5,6] has estimated that out of the total fuel consumption in Manitoba's industry of 33.1×10^6 GJ/yr, (Table 6.1) about 19.5×10^6 GJ (33%) is rejected. (Table 6.2) The distribution by temperature of this waste energy is as follows:

TABLE 6.2

Estimated Rejected Energy in Manufacturing

Group	°F	10^6 GJ	%
A	500 - 1500	4.8	24.5
B	212 - 500	6.3	32.3
C	120 - 212	4.0	20.5
D	Less than 120	4.4	22.7
		19.5	100.0

Group A waste heat figures consist mostly of energy contained in industrial gases found in the steel and metal processing plants. Most of the waste energy streams specified by Group B come from the boiler stacks as flue gases. Only a small part of this group's energy flow is in the form of steam rejected by the chemical and food processing industries.

Waste heat streams in Groups C and D are mostly hot liquids (water, oil, chemicals, etc.) used for cooling of industrial processes, equipment, or products, or it is steam condensate which is not returned to the boiler. Ventilation heat rejected from buildings is also in this group.
Table 6.2 shows that the highest opportunity of waste heat recovery is in Group B with 32.3% of the total waste heat stream. Next in magnitude is Group A with 24.5%.

Almost all manufacturing establishments reject heat into the environment. The recovery of this heat for useful purposes is determined by the economics of installation, technical expertise and operating manpower.

The temperature and quality of rejected heat streams vary considerably between industries and even between companies in the same industry, depending on the specific complement of industrial processes and equipment. However, there are only three principal sources of rejected heat:

1. Combustion equipment which exhausts flue gases at relatively high temperatures:
   - 500 - 1500°F furnace and kiln flue gases
   - 350 - 500°F boiler flue gases
2. Process losses, generally liquids at moderate to low temperatures:
   - 120-212°F condensate and process water
   - lower than 120°F condenser cooling water
3. Gas turbines and diesel engines which have high temperature gases, exhausts and cooling water streams.

In general there are six steps required to implement a heat recovery project. They are as follows:

1. Identify the quality and quantity of waste heat stream; Assess the technical feasibility of the stream;
2. Determine the uses for the recovered heat and its time of use; Prepare the heat balance calculation on a time scale;
3. Specify heat recovery equipment, a transportation system, and storage if required;
4. Calculate the economic feasibility of the proposed heat recovery system;
5. Purchase and install equipment;
6. Prepare operating and maintenance manual and schedule.

6.2 Technical Considerations

Each energy recovery system is largely unique and site-specific, requiring a variety of equipment connected by a system for transferring, and possibly storing heat energy. Many industrial plants lack the necessary energy demand

characteristics for recovering rejected heat, due to variations in operating procedures or, to the small volume of waste heat involved.

Furthermore, heat energy usually has a low energy content per unit of volume compared to other energy sources such as fossil fuels. For this reason it may be technically more complicated to accomplish within a plant, due to the larger volumes involved. Space and routing limitations in a retrofit situation may be a particular problem.

Industrial operations which are considering the utilization of waste heat recovery techniques will have to consider a number of technical factors such as:

Quality: Waste heat streams which are extremely corrosive to heat exchangers and other equipment are not suitable for recovery. Only clean, non-corrosive, and relatively safe streams can be considered at this time. Others must wait for suitable equipment and techniques to be developed.

Quantity: Waste heat streams are often too small or too dispersed to be economically collected and recovered. A large volume from a single source is the ideal situation.

Heat Balance: The ability to match the source of heat and its use is a key factor. Re-scheduling of operations or energy storage may be necessary to achieve a level energy load. In cases where this is not possible within an industrial plant, conversion to another form of energy, such as electricity or compressed air, may help to provide an internal use or to find a market outside the plant boundary.

Personnel: Qualified operators, supervisors, maintenance and managerial personnel are necessary for the successful implementation of a waste heat recovery system.

Monitoring and Control: Accurate metering devices and efficient control systems will be an important component of an efficient, safe, and reliable energy cascading system operation.

The recovery and re-use of waste heat involves a balance of requirements. The reliability factor requires that considerable care be taken not to make the plant operations unnecessarily complex. Back-up energy sources and systems may be necessary to ensure availability in case of shutdowns or other disruptions. The energy transfer system must be sound, as breakdown in an item such as a heat exchanger could result in contamination of process fluids,or equipment, or products. Optimizing the design and performance characteristics of each unit operation as well as the total system is the overall key to success.

6.3 Sources of Waste Heat

6.3.1 Industrial High Temperature Furnaces

In Manitoba there are 39 industrial establishments where high temperature furnaces may be used:

Primary Metals	12
Non-Metalic Products	22
Petroleum Products	5
	39

In these industries furnaces are used to do the following: [7,8]

1. Heat and melt metals,
2. Heat treat metals,
3. Dry and bake cement, bricks, ceramics, etc.

The energy in exhaust gases from such furnaces can be recovered to reduce the amount of purchased fuel. There are three possible uses for the energy obtained from the gases: [9]

1. To preheat combustion air going to the furnaces,
2. To produce hot water or steam,
3. To preheat process materials.

There is equipment on the market which can readily be used for such applications. For preheating of combustion air, gas/gas heat exchangers such as recuperators and regenerators can be used. These heat exchangers extract some heat from the escaping flue gases and return it to the furnace by preheating the combustion air. In recuperators, a continuous flow of hot gases and cold entering air (or gas) is maintained through metal or refractory ducts, which keep the two gas streams apart, but which conduct heat from the hotter to the colder stream. The over-all coefficient of heat transfer in metallic recuperators is between 2.5 and 6.0 BTU/ft^2/hr/°F or 14 and 34 W/m^2/hr/°C.

Regenerators are used where high temperatures of air preheat are required to maintain a high furnace temperature (soaking pit or billet heating furnace). Regenerators are more expensive than recuperators in most cases and are not frequently used except in the steel producing mills.

The saving by the heat exchangers depends upon the temperature to which incoming air is preheated. With a flue gas temperature of 1600°F, the theoretical saving in fuel is as follows:

Temp. of Preheated Air °F	% Saving
200	4
400	11
600	15
800	19

6.3.2 Boiler Flue Gases

All fired boilers require combustion air and produce flue gases. The flue gases are usually in the 400° to 600°F range. This temperature can be reduced by removing heat for combustion air preheat or for heating water in an economizer. In the past, manufacturers of boilers produced combustion systems which reject flue gases over 500°F to reduce the corrosion of boilers.

A problem develops as the economizer pressure mounts to reduce the stack temperature below its acid dew point. For this type of application, corrosion cannot be avoided even by using expensive, exotic alloy tubing. It must be

accepted that source steel, like fuel, will be consumed in the processes.

Economizers remove heat from the moderately low-temperature combustion gases after the gases leave the steam-generator. Economizers are forced-flow, once-through, convection heat transfer devices, usually consisting of steel tubes. Hot water produced by this heat exchanger can be used as feedwater to the boiler or for other applications.

The size of an economizer is governed by economic consideration involving the cost of fuel, capital cost, thermal performance, relative cost of air heater, the hot water temperature, and the desired flue gas temperature. The temperatures of the economizer tube metals generally approximate those of water in the tubes.

The tubes therefore, can be at temperatures where condesation can take place. Since most of the fuels used in Manitoba contain various amounts of sulphur, corrosion of the economizer may take place when flue gas is cooled below the dew point by recovering too much energy from the gas.

Air heaters, like economizers, remove heat from the flue gases. The heat recovered from the combustion gases is recycled to the furnace with the combustion air, resulting in a gain in the overall thermal efficiency. The use of preheated combustion air accelerates ignition and promotes rapid and complete burning of the fuel.

Air heaters are classed as recuperators or regenerators. These are discussed in section 6.3.1

Corrosion of air heaters is a problem where the flue gas temperature is reduced below 300°F. However, the best way to deal with the corrosion problem is to take it into consideration during the design stages, and provide a separate corrosion section arranged to facilitate the replacement of the vulnerable cold-end portion.

An air preheater can save 10-30% of the fuel used in the boiler.

6.3.3 Heat Recovery from Hot Liquids

Many industries, and especially the food and beverage, the chemical products, and the petroleum products industries reject large quantities of heat in their processes. In most cases this energy is contained in water which is used as a cooling medium.

In the processing of food, hot water or steam is used for:

- cooking
- pasteurizing
- cooling
- cleaning

The waste heat stream is usually in the 90°F to 150°F range. In many cases the rejected hot water contains contaminants such as food solids, and requires additional processing or filtering before the heat can be recovered. Liquid/liquid heat exchangers can be used to transfer the heat in the waste stream to preheat either the process water or the product.

In dairies, recovered hot water can be used for preheating milk in pasteurizers, for clean-up water, or for preheating the boiler make-up water.

The difficulty arises when the waste heat production is not in phase with the heat demand. In this case, storage facilities for hot water must be provided, from which the hot water can be distributed to the appropriate applications.

Another source of heat in the food and beverage industry is that produced in the condensers of the refrigeration equipment. The cooling water from condensers is at about 90° to 120°F, and it is clean. It can be used directly in the plant, or the temperature can be elevated by a heat pump to between 160° to 180°F. At this temperature most of the cooking and pasteurizing equipment can be supplied with this water. Evaporators and cooling towers can also provide energy for heat pumps.

6.4 Equipment for Heat Recovery

6.4.1 Heat Pumps

The major manufacturers of packaged industrial high temperature heat pumps in North America are Westinghouse Electric Corporation and Carrier Corporation. Figure 6.1 shows a schematic diagram of a Westighouse product called "the Templifier". The heat pump cycle is the same as the refrigeration cycle except that the temperature levels have been changed.[10] This requires the use of different refrigerants. The heat pump is capable of recovering low grade waste heat in the temperature range of 16°C to 49°C. The waste heat from the source water is absorbed in the evaporator by the refrigerant. The temperature and pressure is increased by the compressor. From here the refrigerant goes to the condenser where its heat is transferred to process water raising its temperature up to 220°F.

A useful measure of the heat pumps effectiveness is the C.O.P. or coefficient of performance. The C.O.P. is a ratio of the heat output from the unit to the energy input to run the compressor or compressors. A C.O.P. of 4 signifies four units of useful output energy for one unit of input energy.

The C.O.P. of the Templifier unit varies depending upon the available source temperature and the required application temperature. The curves shown in Figure 6.2 describe the operating characteristics of the centrifugal Templifier heat pump. Under the conditions where the source water is 95°F (35°C), the Templifier can cool this water to 85°F (30°C) and supply hot water at 160°F (71°C) with a C.O.P. of 5.8.

FIGURE 6.1

SCHEMATIC DIAGRAM OF THE TEMPLIFIER

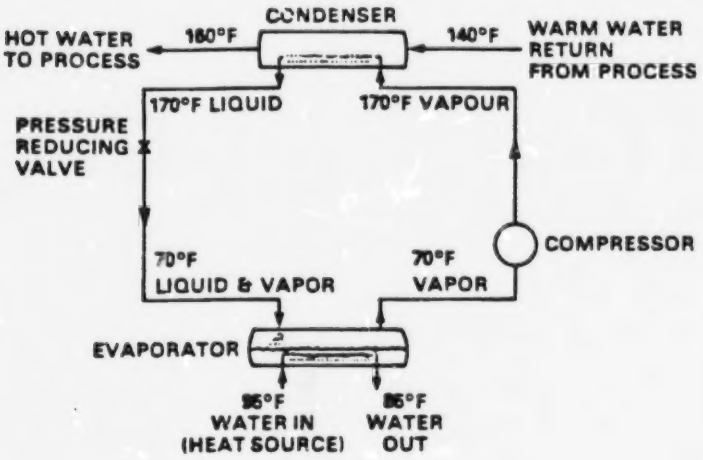
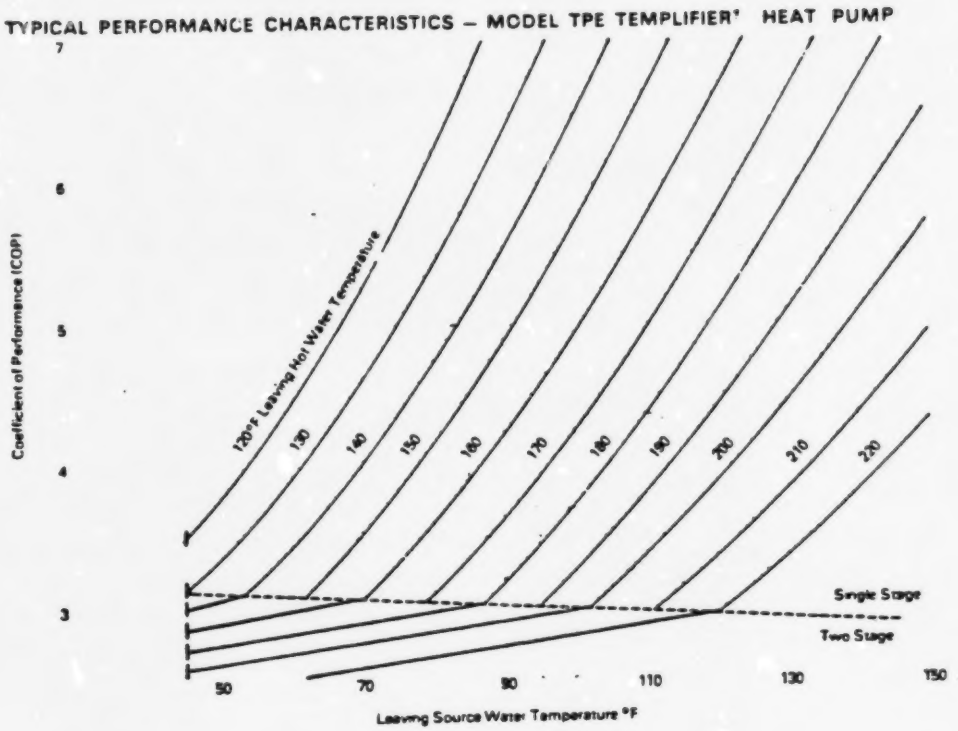


FIGURE 6.2



6.4.2 Heat Exchangers

In order to remove heat from one source and introduce it to a different onè, a heat exchanger is used. Heat exchangers usually consist of nothing more than metal walls separating the two sources, which can be either liquids or gases. The amount of heat that can be transferred in a given time is proportional to the surface area of metal that each stream is in contact with and the temperature difference. By paralieling the flow of liquids in the heat exchangers the space occupied by the unit is reduced.

Fluid proportions determine the type, construction or material of heat exchanger that is most suitable. Some of the more common heat exchangers are:

(a) liquid to liquid
(b) gas to liquid
(c) gas to gas

6.4.2.1 Liquid to Liquid

Heat contained in one liquid can be transferred to another with the use of a liquid to liquid heat exchanger. Since liquids are usually under pressure it is necessary that both paths be sealed to contain the liquids. This led to the shell and tube heat exchanger, the most common type of liquid to liquid exchangers. In the process industry, shell and tube heat exchangers are in evidence in many applications because the temperatures of waste heat in liquid are relatively low, say at 25 to 35°C. To recover this energy would require large size exchangers and the resultant liquid would be at too low a temperature for economical use.

One exception to this rule is the use of low quality heat with an industrial heat pump. With this process, energy in liquid at 25 - 35°C can be recovered, increased in temperature to 80-90°C, and either used in some process or used to heat space.

The cost of heat exchangers vary according to the type, temperature difference, and material used. As the temperature of the source increases,

the cost per GJ recovered drops. For a 10 GJ/hr unit with 95°C source, the estimated cost is about $10,000, which is about twice the cost of the low pressure boiler fired with natural gas. The size of the heat exchanger surface for such a low source temperature is many times that of the boiler.

6.4.2.2 Gas to Gas

The most common application of this exchanger can be found in the recovery of heat from flue gas to preheat combustion air. Materials for heat exchangers are selected on the basis of corrosion resistance, ease of fabrication, temperature levels, strength and cost. In general up to 420°C carbon steel is used but for higher temperatures stainless steel is utilized. In Nova Scotia industries, several applications exist where hot gases can be recovered with gas to gas heat exchangers. In furnaces and boilers there is an opportunity to save energy.

A commonly used gas to gas heat exchanger, often referred to as a heat wheel, is used for recovery of low quality heat from ventilation air at 70°-90°F to preheat the make-up air for buildings and factories. The heat exchanger in this case is a regenerator. It is a cylinder about 12-14 inches high, varying in diameter from 6 to 12 feet, depending on the recovery capacity required. The cylinder rotates between the exhaust air and fresh intake air undergoing successive heating and cooling cycles and transferring heat by the termal storage capacity of the cylinder or wheel. The storage medium is fine metal wool. The working temperature determines the metal but the most common medium is aluminum and stainless steel.

This recovery system requires that all exhausts from which heat is to be recovered be brought to one location so that the total exhaust will be made to pass through one-half of the wheel. Similarily all of the supply air must be passed through the other half of the wheel before being distributed to its final destination. The transfer of heat takes place as the medium in the wheel rotates slowly through first the hot exhaust

and then through the cool supply, picking up heat on one side and giving it up on the other. Where the temperature difference is high enough, efficiencies of 80% are realized.

All wheels allow some cross-contamination to take place. Some exhaust air leaks back into the supply side through seals, the effectiveness of which is a function of the pressure difference across the ducts; some is entrained in the transfer medium and carried from one duct to the other as the wheel rotates.

Cross-contamination can be controlled by properly arranging the location of supply and exhaust fans so as to make the pressure on the exhaust side negative with respect to the supply side and by use of a purging unit. This is a small pie-shaped blind section, which causes some of the supply air to blow out or purge the trapped air in the wheel through the exhaust as each segment of the wheel passes the purging unit. Carry-over of less than 1% can be achieved with only a small loss in efficiency.

Finally, since the two ducts are located so close together, care must be taken outside the building to ensure that exhaust does not get back into the intake. This is usually done by separating them as far as possible.

Obviously then, a heat wheel can recover heat from any exhaust that can be made to pass through it.

However, the material in the wheel does limit the temperature allowable. Wheels filled with aluminum metal mesh or corrugations are limited to 300°F. Stainless steel will usually go to 600°F. Above that ceramic material is used, but even it has an upper limit of about 1500°F. At this temperature, the main problem is to find flexible material with which to seal the wheel and it is very difficult to match the expansion factors of a ceramic wheel to a steel axle and steel shell. Another limitation is size as the largest ceramic wheel is only 4 feet in diameter. The best solution is to reduce the temperature of the exhaust by mixing it with cold air to about 500° - 600°F where standard high temperature wheels can handle it very easily.

6.4.2.3 Gas to Liquid

The most common gas to liquid heat exchanger is used to recover waste heat streams to produce process steam. Equipment used for this purpose is known as waste heat boilers, and these boilers are available in a wide range of sizes. Many mineral processing plants emit large quantities of hot gases at 600-800°C from industrial furnaces, which, when passed through a waste heat boiler, produce high quality steam.

Three establishments responding to the survey have this opportunity for heat recovery.

Another application of a gas to liquid heat exchanger is known as an economizer which was described in section 6.3.2. Many respondents the survey have flue gases at 250-300°C which can utilize an economizer to recover some energy from the flue gas.

6.4.2.4 Run-Around System

All of the heat exchangers discussed above are characterized by the fact that both the medium gaining the recovered heat and the waste heat must be brought to the same place and passed through the same device. This can be awkward and expensive. The well known "run-around system" of heat recovery overcomes this problem by pumping a heated medium such as water or glycol between two heat exchangers. The exchangers which must be of the liquid type, may be placed anywhere in a building or buildings. A pump drives a transfer liquid through interconnecting pipes. Such systems must be custom designed, and while ther usefulness is readily apparent, one must be aware that their efficiency is low; less than 50%. The distance the heat can be moved is a function of the quality and quantity of heat involved and price of fuel.

At present with temperature differences of 20°C or higher between the hot and cold headers, a 10 GJ/hr system is usually economic for a distance of 200 m. A 50 GJ/hr system can move the heat economically up to 1000 m.

6.4.2.5 Heat Pipe

Another static device for heat recovery purposes is called a "Heat Pipe". The Heat pipe uses a fluid sealed inside the pipe which vapourizes when heated and moves quickly to the cold end when it condenses. The liquid condensate then runs back to the hot end by capillary action. It is thus able to transfer heat faster and in much larger quantites than conduction because advantage is taken of the latent heat of vapourization.

The medium usually used is Freon Liquid for low temperature work, but obviously any liquid would work providing there is enough heat to vapourize it. Even solids can be used, and heat pipes have been built using sodium metal, lead and even exotic metals which vapourize at temperatures higher than 2000°F. However, the construction and sealing of such devices becomes exceedingly difficult and an upper limit of 500°F is all that is practical.

In use, individual heat pipes are bundled into standard frames, with a divider to separate the hot and cold gas or liquid streams. It is interesting to note that the divider can be placed off-centre to accommodate unequal air volumes if desired. Construction of the tubes is usually of copper or aluminum, but they can be made of any metal to accommodate various temperatures. They can be finned to increase heat transfer, and coated to resist corrosive gases.

Efficiency of heat recovery is influenced by the number of rows of heat pipes, fin spacing, stream flow rate and temperature difference. It varies from 50% to 70%.

Although heat pipes are presently on the market, the capital costs would be too high for industrial use. No application of this device is found in Manitoba.

6.5 Cost Estimates of Waste Heat Recovery

Cost estimates for waste heat recovery systems include:

(a) capital cost comprising equipment and installation
(b) operating cost
(c) engineering cost

The cost associated with loss of production due to interruptions when equipment is being installed is not included. In most cases this cost is small but installation of equipment in the primary metals industries, refineries or cement manufacturing plants may require prolonged interruption in production schedules and necessitate a close coordination with the periodic maintenance schedules.

In estimating the capital cost of a waste heat recovery project, the most important single item is the cost of engineering to evaluate the potential sources of heat, identify suitable equipment, and design the system. Evaluation of the potential can be as high as 50% of the total capital cost. Since each project is site specific, evaluation must be done from first principles. This evaluation in many cases proves that the project is uneconomic and has to be abandoned. The investment in engineering has to be written off against other projects or against the operating budget. This initial step can be risky, which discourages many plant managers from undertaking such energy conservation projects.

However, if the evaluation is positive then the subsequent steps are relatively easy. Locating the necessary suppliers and the detailed process design is less than 10% of the total capital cost. Searching for an economic waste heat recovery project is similar to searching for oil. Dry holes are very common.

Capital costs for various energy recovered systems were developed from cost data received from equipment manufacturers and from our own files on installation costs. This data was compiled and presented in graph form as shown in figures 6.3 to 6.6.

From the survey, an energy recovery system is determined for each establishment supplying the required information. Capital costs from the cost curves were applied to the system and then the operating and additional costs were estimated. Operating and maintenance costs vary between 2 and 4% of the capital cost, while additional energy required to run fans, pumps, controls, etc. is estimated for each establishment separately. Electricity use for heat pumps is obtained from the size of the heat pump, load factor and coefficient of performance. These costs are shown in Table D-1 in Appendix D. Table 6.3 summarizes the data contained in Table D-1.

TABLE 6.3

SUMMARY OF FINANCIAL DATA

Energy Recovery - Manufacturing in Manitoba

1.	Number of Establishments -	34
2.	Energy Saving -	2,366,750 GJ/yr
3.	Value of Energy -	$ 6,842,310 /yr
4.	Capital Cost -	$23,553,200
5.	Operating Cost & Energy -	$ 2,457,260
6.	Savings (Item 3 - Item 5) -	$ 5,333,750
7.	Pay-back (average) -	4.41 Years

6.6 Potential and Opportunities

It is believed that the respondents to the survey, which are tabulated in Appendix D, represent about 75% of the total energy use in Manitoba. Since the sample for the survey was not randomly selected this figure is only an experienced estimate and not statistical. This is based on the estimate of large users which are shown in Table 6-4. This group of 219 establishments, or 32% of the total in Manitoba, represent almost 92% of the total energy used by the province's industries. The sample contained all the large energy users shown in Table 6-4.

Therefore, if the sample represents 75%, the total potential energy saving would be 3,150,000 GJ/year at a capital investment of about $31,000,000 with a pay-back period of 4.4 years.

TABLE 6-4

ESTIMATE OF FUEL USE
ENERGY INTENSIVE INDUSTRIES
MANITOBA - 1976

Industry	Establishments	10^9 BTU	% of All Industries
Food & Beverage	135	5797.2	17.5
Paper & Allied Products	20	6996.0	21.1
Primary Metals	12	4448.2	13.6
Non-Metalic Minerals	22	6275.0	18.9
Petroleum Products	5	4862.0	14.7
Chemical Products	25	2003.4	6.0
TOTAL	219	30381.8	91.8
All Industries	684	33146.2	100.0

Figure 6.3

Estimated Installed Cost for
Liquid-to-Liquid Heat Exchangers

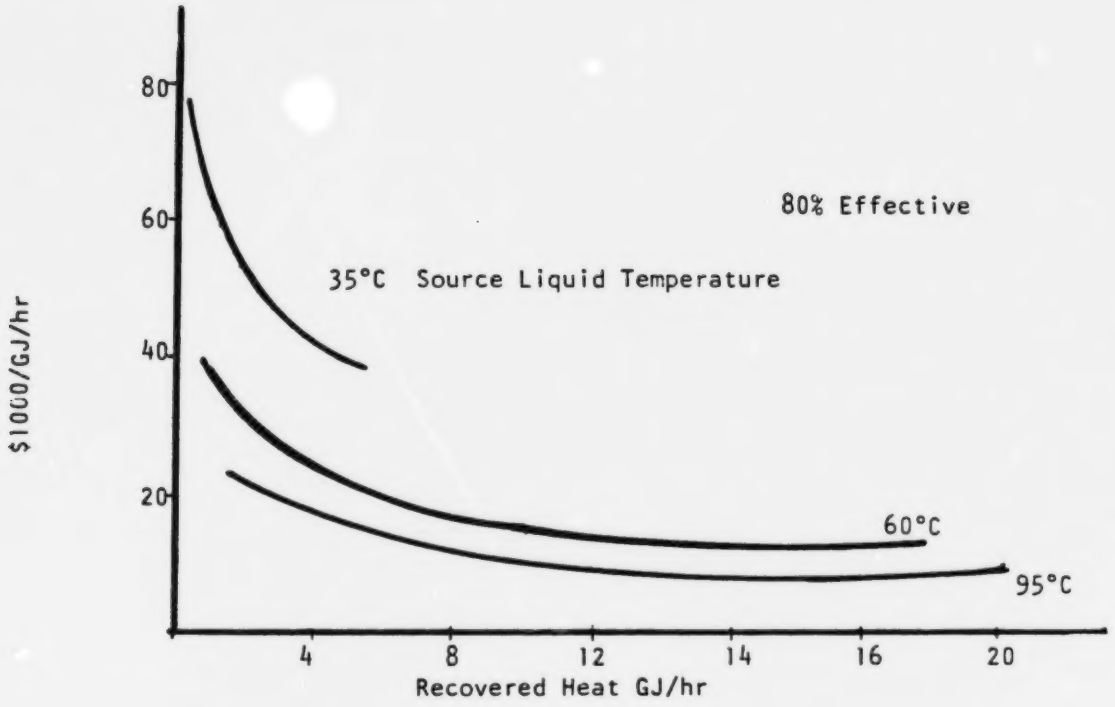


Figure 6.4

Estimated Installed Cost for
Gas-to-Gas Heat Exchangers

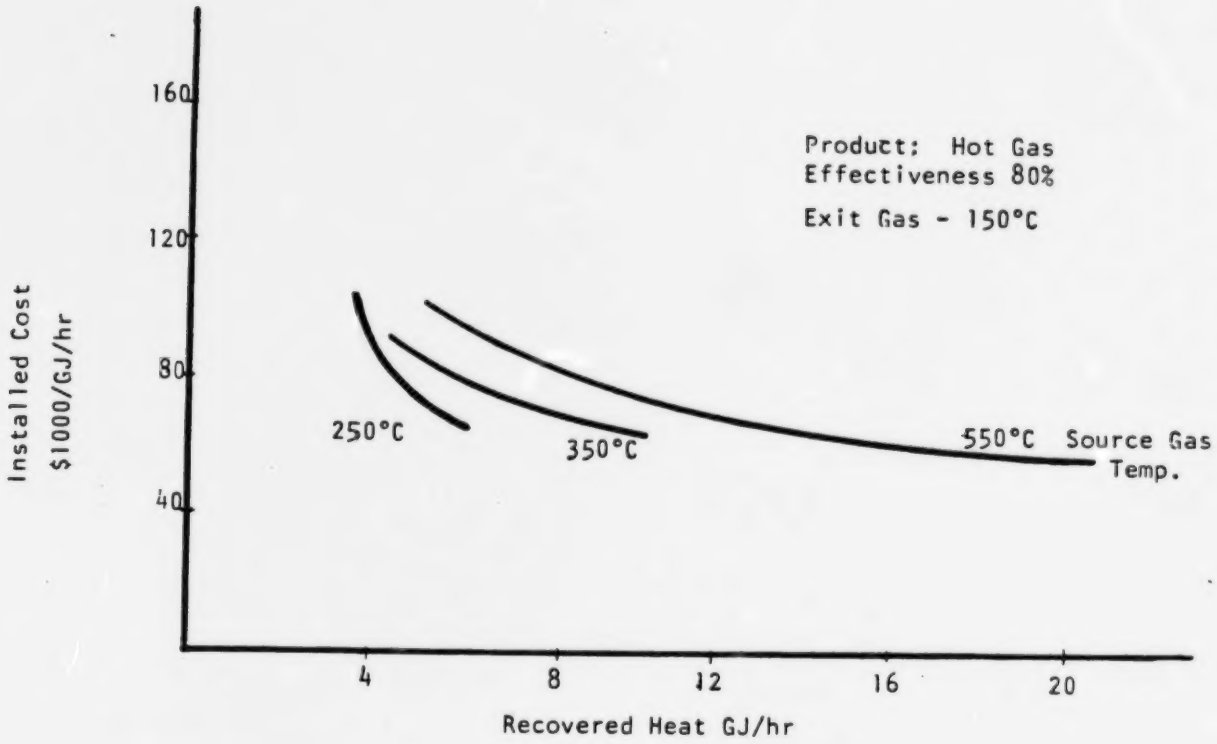


Figure 6.5

Estimated Installed Cost for
Gas-to-Liquid Heat Exchangers

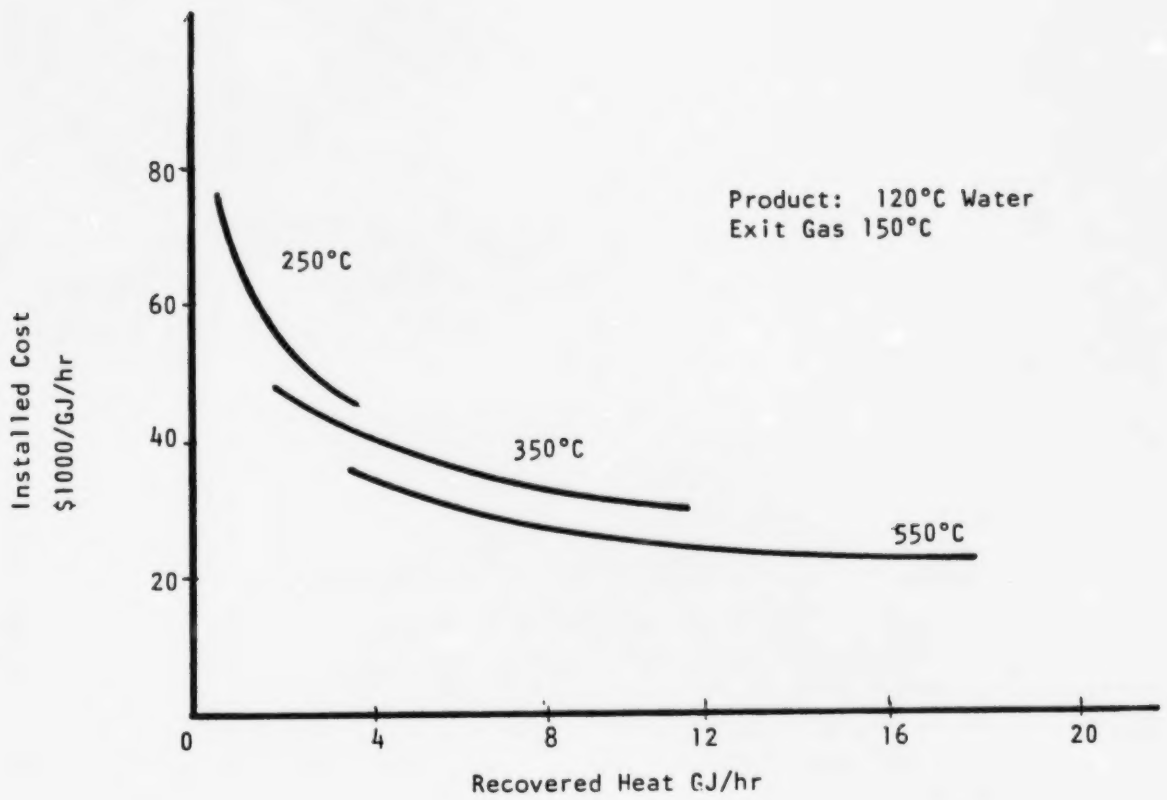
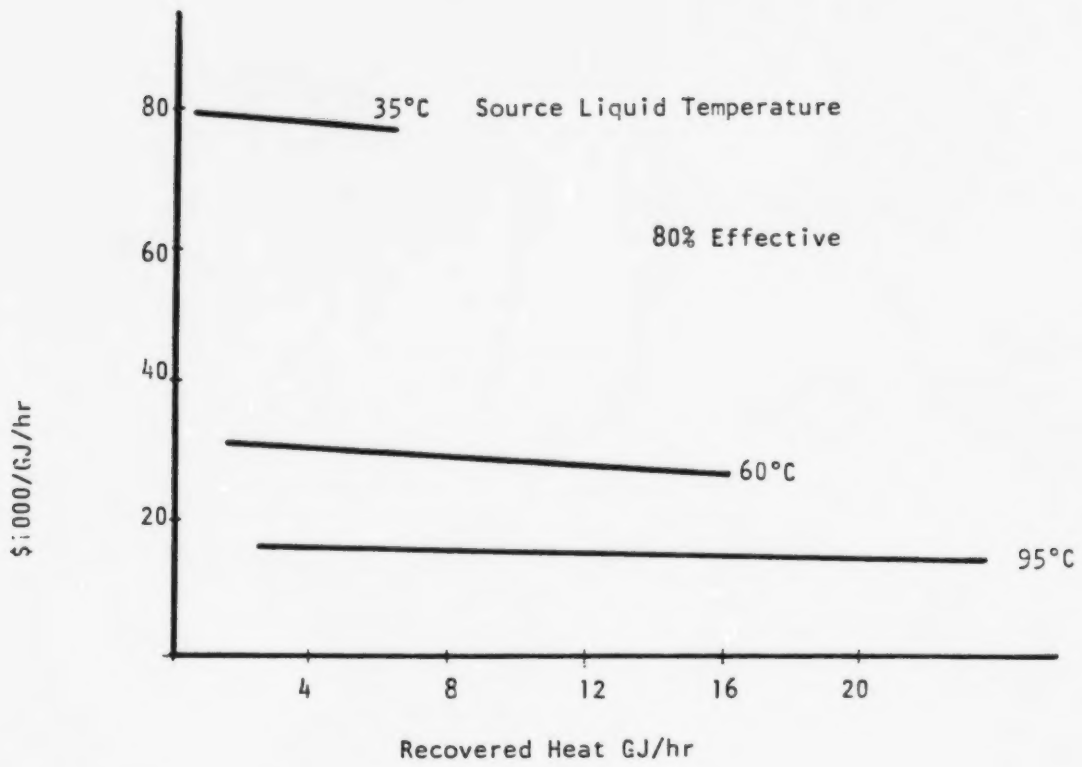


Figure 6.6
Estimated Installed Cost for
Liquid-to-Gas Heat Exchangers



7.0 INSTITUTIONAL BARRIERS

7.1 Cogeneration

Many industrial managers do not consider electrical power generation as part of their business, regardless of economics, and will not develop the technical potential of their establishments. The reason for this attitude, in most cases, has evolved over many years from the relationship between the electric public utility and its customers. This relationship has been institutionalized, and as a result has become a barrier to the development of cogeneration.

One of the most important barriers to be overcome in Manitoba, although related to economics, is an institutional one. It is the price of electricity charged by Manitoba Hydro. This price is not set by the market place. Since it has been frozen at the 1980 level, the present cost of $0.0165/kWh to large power customers is well below the cost of electricity from other hydro-electric systems in Canada such as Hydro-Quebec and B.C. Hydro.

Financing of cogeneration projects is also different for industry from that of Manitoba Hydro. The cost of funds is much higher for industrial establishments than it is for Manitoba Hydro which is a crown corporation. In general, industrial managers demand a higher rate of return from cogeneration plants than do utilities. Many potential projects which look economic, when viewed from the utility's prespective, are eliminated by the industrial criteria.

There are a number of cogeneration sites in Manitoba which are capable of generating only a small percentage of the total electrical demand. In these cases, there is no need to parallel with the utility and the control of power can be accomplished at the site by simple switching. Here the decision to cogenerate rests with the management and the economics of make-buy, with electricity pricing being the only barrier. However, if establishments were to produce electricity in excess of their own requirements, as they would if the gas turbines were designed to utilize the steam flow requirements in a cogeneration mode, then many

more institutional barriers would come into play.

As a utility's planning horizon is more than 20 years, it wishes to have all future generation well defined, and preferably under its control and not under industry's control. Since industry cannot predict its requirements that far in advance, in most cases the cogeneration potential is not taken into account. Therefore, cogeneration does not receive a contribution in the rate paid by the utility towards the capital cost. For cogeneration, the capital cost is about 40% of the total cost of production, therefore, the utility is willing to pay only for the energy, and not the capital. In most provincial utilities, with the exception of Ontario, the rate at which a utility buys power from a cogeneration station is set at the value of energy. In Manitoba, it is at 1.12¢/kWh. This rate is inadequate to develop cogeneration.

Another constraint to cogeneration is the unavailability of trained personnel to operate and maintain equipment for a secure and economic operation. Most cogeneration operations are too small to train their personnel to the same level of expertise that a public utility such as Manitoba Hydro can. Therefore, the efficiency of many cogeneration plants is lower than that of the utilities.

7.2 Waste Heat Recovery

There are no institutional constraints related to waste heat recovery provided the energy is used internally by industry. However, if an industrial plant decides to sell recovered energy outside its boundaries it must meet many requirements related to right-of-way, environmental regulations, municipal permits, etc. There are no industries at present in Manitoba which are planning to sell their surplus recovered heat to outsiders.

8.0 POLICY OPTIONS FOR MANITOBA

8.1 Cogeneration

At the present time the development of cogeneration by industry is not economical due to the artifically low Manitoba electricity rates to industry. However, these rates will be in effect only until 1985, at which time the rate freeze will expire. At that time, the rates set will most likely reflect the cost of producing power by Manitoba Hydro. Cogeneration, with its lower capital costs and high efficiency, would then be competitive again.

Since it takes a minimum of 36 months to design, contract and commission a cogeneration station, the planning could start now. This could take the form of co-ordination, evaluation, education, training and demonstration.

The Department of Energy and Mines of Manitoba could set up a Task Force aimed at developing cogeneration in the province. This body could comprise representation from industry, Manitoba Hydro, engineering consultants, and boiler and turbine manufacturers. It could be chaired by the Department. Its responsibilities would be to:

(a) provide a forum for exchange of information between Manitoba Hydro and the potential cogenerators,
(b) develop a program and guidelines for evaluation of cogeneration sites by industry,
(c) initiate the education of management and technical personnel in industry with regards to cogeneration, and
(d) set up a training program for operators and maintenance personnel.

This Task Force could also assist the Department of Energy and Mines in selecting a demonstration site. A demonstration of a gas turbine installation in Manitoba could also be used as a promotion of Canada's gas turbine manufacturers, Solar Turbines Canada and Pratt and Whitney.

8.2 Waste Heat Recovery

Manitoba's industry could reduce purchases of fuel by 9 % with the installation of heat recovery equipment. However, to save this energy industry would have to invest in such equipment.
At the present time, they are reluctant to make this investment because of the high cost of capital and the unsettled economic conditions. There are not many heat recovery installations which exist in Manitoba, since the price of fuel has up to now been favourable, and alternatives have not been as important as they are becoming. This picture is changing and a demonstration of waste heat recovery equipment could overcome some of this reluctance by industry to invest.

Although waste heat recovery is a site specific activity, there are common technologies that, if demonstrated in one industry, could find application in other industries. Some of these are:

1. Heat recovery from high temperature furnaces with recuperators,
2. Economizers or air heaters on existing boilers,
3. Heat pumps for the Food and Beverage Industry,
4. Heat wheels in Fabrication and Assembly operations,
5. Run-Around Systems.

A high response to our survey questionnaires (46 of 88) indicates an interest by industry to lower their fuel cost by means of heat recovery. It was also observed that Manitoba has very few salesmen promoting conservation of energy equipment. Therefore, many managers and engineers are unaware of the type of equipment that is on the market and the economics of heat recovery. This information could be supplied to industry through a one-day seminar. It could include the following topics:

1. Sources of waste heat in industry,
2. Uses of recovered heat,
3. Equipment and Cost,
4. Economic Analysis,
5. Financing the capital expenditures.

9.0 CONCLUSIONS

COGENERATION

1. There are 13 establishments in Manitoba technically capable of cogenerating about 212 MW of electricity.

2. The capital cost of this cogeneration capacity of 212 MW is estimated to be $91,312,000 with a pay-back period of 36.97 years.

3. At this time cogeneration in Manitoba is not economically feasible. This is mainly due to the low Manitoba Hydro rates of $0.0165/kWh. At $0.026/kWh the pay-back period would be less than 5 years.

WASTE HEAT RECOVERY

1. Almost all industries in Manitoba reject energy as waste heat into the environment. There are 684 industrial establishments in Manitoba which purchase about 33×10^6 GJ/yr of fuels.

2. It is estimated that 19.5×10^6 GJ/yr is rejected of which 3.2×10^6 GJ/yr can be recovered at a cost of $31 million in capital expenditures. The pay-back period on this investment would be 4.4 years.

3. There are several types of equipment on the market suitable for waste heat recovery. However, our survey indicates that industry is unaware of its existence, its applications and its cost effectiveness.

4. In order to demonstrate various applications of equipment and to ascertain operating costs for Manitoba, four installations using different technologies should be investigated further through:
   (a) feasibility study
   (b) detailed design
   (c) installation of equipment and commissioning.

10.0 RECOMMENDATIONS

COGENERATION

The following recommendations are based on the findings of the survey calculations and our experience in the industrial sector. They are as follows:

1. Set up a cogeneration committee to do the followings:
   (a) provide a forum for exchange of information between Manitoba Hydro and the potential cogenerators,
   (b) develop a program and guidelines for evaluation of cogeneration sites by industry,
   (c) initiate the education of management and technical personnel in industry with regards to cogeneration, and
   (d) set up a training program for operators and maintenance personnel.

WASTE HEAT RECOVERY

1. Organize and conduct three one-day seminars on waste heat recovery technology and methods. These seminars should be held close to the appropriate industries to guarantee a good attendance. Recommended locations are:
   1. Winnipeg
   2. Brandon
   3. The Pas

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APPENDIX A

Sample of Establishments

for

Manitoba Survey

Volume II

REPRESENTATIVE SAMPLE OF COMPANIES WITH GOOD POTENTIAL FOR WASTE HEAT RECOVERY AND COGENERATION

Canada Packers Inc., Winnipeg
Manitoba Dairy Co-operative, Winnipeg
Manitoba Forestry Resources, The Pas
Abitibi Price Inc., Pine Falls
Hudson Bay Mining and Smelting, Flin Flon
Inco Metals Co. - Manitoba Div., Thompson
Burns Meats Ltd., Winnipeg
Carnation Foods Co. Ltd., Carberry
United Grain Growers Limited, Winnipeg
Interbake Foods Limited, Winnipeg
Old Dutch Foods Limited, Winnipeg
Labatt Brewing Co. Ltd., Winnipeg
Simplot Chemical Co. Ltd., Brandon
Shell Canada Limited, St. Boniface
Bristol Aerospace Limited, Winnipeg
Boeing of Canada Ltd., Winnipeg
Genstar Ltd., Winnipeg
Manitoba Rolling Mills Ltd., Selkirk
Dominion Bridge Co. Ltd., Winnipeg
Monarch Industries Limited, Winnipeg
Versatile Cornat Corp., Winnipeg
Federal Pioneer Limited, Brandon
Motor Coach Industries Limited, Winnipeg
Readyfoods Limited, Winnipeg
Burns Meats Ltd., Brandon
Friendly Family Farms Ltd., Winnipeg
East-West Packers (1969) Ltd., St. Boniface
Canada Packers Inc.-Poultry Div., Winnipeg
Swift Canadian Co. Ltd., Winnipeg
J. M. Schneider Inc., Winnipeg
Modern Dairies Limited, Winnipeg
Campbell Soup Company Limited, Portage La Prairie
Scott-Bathgate Limited, Winnipeg

Federal Co-Operatives Ltd., Winnipeg
Maple Leaf Mills Limited, Winnipeg
Ogilvie Mills Ltd., Winnipeg
Weston Bakeries Limited, Winnipeg
McGavin Foods Limited, Winnipeg
B.C. Sugar Refining Co. Ltd., Winnipeg
C S P Foods Ltd., Altona
Calvert of Canada Limited, Gimli
Coca-Cola Ltd., Winnipeg
Westeel-Rosco Limited, Winnipeg
Abex Industries Ltd., Selkirk
Griffin Steel Foundries Ltd., Transcona
Teledyne Canada- Foundries Div., Winnipeg
Monarch Industries Ltd., Winnipeg
Canada Wire and Cable Limited, Winnipeg
Canadian Bronze Company Ltd., Winnipeg
Bay Bronze Industries Ltd., Winnipeg
Joy Mfg. Co. (Canada) Ltd., Winnipeg
E.H. Price Limited, Winnipeg
Behlen-Wickes Company Limited, Brandon
Dominion Bronze Limited, Winnipeg
Dominion Bridge Co. Ltd., Winnipeg
Greensteel Industries Limited, Winnipeg
Metal Industries Limited, Brandon
Canadian Tool & Die Ltd., Winnipeg
Durall Limited, Winnipeg
Co-Op Implement, Winnipeg
Canadian Co-Operative Implements, Transcona
Macdon Industries Ltd., Winnipeg
CEA Simon-Day Ltd., Winnipeg
Sullivan Strong Scott Ltd., Winnipeg
Princess Auto & Machinery Ltd., Winnipeg
Chicago Blower Canada Ltd., Winnipeg
Fort Garry Industries Ltd., Winnipeg
Burroughs Business Machines, Winnipeg
CAE Aircraft Limited, Winnipeg
Winnipeg Supply & Fuel Co. Ltd., Winnipeg
Coldstream Products of Canada, Winnipeg

Flyer Industries Limited, Winnipeg
Motor Coach Industries Ltd., Winnipeg
Budd Canada Inc., Winnipeg
Sheller-Globe Manitoba Ltd., Morris
Marr's Leisure Products (1977), Rivers
F.P. Newspapers Limited, Winnipeg
Southam Inc., Winnipeg
National School Services Ltd., Winnipeg
Canadian Publishers Co. Ltd., Winnipeg
Stovels-Lawson Graphics Man, Winnipeg
Moore Corp-Business Forms Div., Winnipeg
Reliance Products Limited, Winnipeg
Winpak Ltd., Winnipeg
Crown Zellerback Flex-Pak Ltd., Winnipeg
United Canadian Shares Ltd., Winnipeg
Canada Cement Lafarge Limited, Fort Whyte

APPENDIX B

SAMPLE QUESTIONNAIRE

THE PROVINCE OF MANITOBA

INDUSTRIAL ENERGY SURVEY

1. ANNUAL ENERGY CONSUMPTION DURING 1980:

Energy Source	Consumption	Total Cost
a) Electricity (kWh)		
b) Fuel Oil (gallons)		
c) Other (Specify)_____		

2. ENERGY INTENSIVE PROCESSES:

Name of Process	Energy Source (electr.,oil,other)	% of Total Energy Cost
a)		
b)		
c)		
d)		

3. SOURCES OF WASTE HEAT: If the following is exhausted from processes in your plant, please indicate:
HOT AIR, STEAM, HOT GAS, WARM WATER, WARM LIQUIDS

Name of Process	Type of Exhaust	Quantity of Exhaust (cfm/gpm)	Temperature of Exhaust °F°C)
a)			
b)			
c)			
d)			

4. ENERGY EQUIPMENT:

a) BOILERS - Capacity _____(lbs/hr, BTU/hr,horse power)

- Operating Pressure _____(psig, kPa)

- % of condensate return _____

b) REFRIGERATION EQUIPMENT

- Installed capacity _____(tons or horse power)

- Application _____

c) OTHER EQUIPMENT

Furnaces _____Kilns_____Ovens_____

5. PLANT OPERATIONS:

Daily hrs. of operation_____No. of operating days/yr_____

Size of plant_____(sq. feet)

APPENDIX C

COGENERATION COST CALCULATION

APPENDIX C

SAMPLE CALCULATION

1. Industry: PULP AND PAPER
2. Site: #29
3. Operating Time: 8000 hours per year
4. Fuel: Oil & Coal at $3.20/GJ
5. Power Rate from Hydro: $.0165/kWh
6. Power Produced: 144.9 GWh
7. Fuel Used for Electricity: 581,800 GJ

Financial Data

8. Capital Cost: $11,408,000
9. Operating Cost: $220,000
10. Fuel Cost (incremental): $1,862,000
11. Replaced Electricity: $2,406,000
12. Saving [Item 11 - (Item 9 + Item 10)]: $324,680
13. Payback Period: 11,408,000/324,000 = 35.2 years
14. Payback with Electricity at $.025/kWh 7.3 years

APPENDIX C

TABLE C-1

COGENERATION PARAMETERS - STEAM TURBINE

Site Code	Potential Cogeneration MW	Produced Energy MWh	Incremental Fuel 1000 GJ/yr	Cost of Fuel $/yr @ 3.20	Capital Cost '000 $	Operating Cost '000 $ 2%	Cost of Replaced Electricity '000 $	Saving '000 $	Pay-back yrs.
42	3.7	17,900	74.5	238.4	2,886	60	358.1	59	48.9
29	18.4	144,900	581.8	1,862.0	11,408	220	2,406.6	324.	35.2
27	5.0	38,700	161.2	515.8	3,500	70	646.4	60	58.3
32	5.4	42,600	173.0	553.6	3,672	73	707.2	80	45.5
16	7.9	64,500	262.0	838.4	5,056	105	1,058.9	-115	
28	3.6	29,000	116.5	372.8	3,700	74	478.2	31	119
Total	44.0	337,600	1,369.0	4,381.0	30,222	602	5,655.4	441.5	68.53

COGENERATION PARAMETERS - GAS TURBINE

42	16	128,000	5,760	1,843	5,390	78	2,115	194	27.8
29	50	400,000	1,800	5,760	16,100	180	6,610	670	24.0
27	12	96,000	432	1,382	4,300	55	1,586	149	28.9
28	10	80,000	360	1,152	3,900	50	1,322	120	32.5
16	22	176,000	792	2,534	7,800	105	2,908	269	28.9
32	25	200,000	900	2,880	8,300	115	3,305	310	26.8
8	15	120,000	540	1,728	5,100	75	1,983	180	28.3
9	3	24,000	108	346	1,600	30	397	21	26.2
14	5	40,000	180	576	2,600	35	661	50	52.0
17	4	32,000	144	461	2,100	30	529	78	55.2
26	2	16,000	72	230	1,300	25	264	9	151
31	2	16,000	72	230	1,300	25	264	9	151
39	2	16,000	72	230	1,300	25	264	9	151
	168	1,344,000	11,232	19,352	61,090	828	22,201	2,028	30.12

APPENDIX D

WASTE HEAT RECOVERY COST CALCULATION

APPENDIX D

TABLE D-2

WASTE HEAT RECOVERY IN MANITOBA

INDIVIDUAL SITE

SAMPLE CALCULATION

1.	Industry:	Food and Beverage
2.	Site:	24
3.	Equipment:	Heat Pump
4.	Operating Time:	6000 Hrs/yr
5.	Operating Energy:	Electricity
6.	Cost of electricity:	$2400/yr
7.	Fuel:	$3.50/GJ

Financial Data

8.	Capital Cost:	$18,000
9.	Operating Cost:	$ 2,400
10.	Fuel Saved:	$ 6,820
11.	Savings (item 10 - item 9):	$ 4,420
12:	Pay-back period (item 8/item 11):	4.1 years

APPENDIX D

TABLE D-1

ENERGY RECOVERY POTENTIAL IN MANITOBA

FINANCIAL DATA

ESTABLISHMENT NUMBER	ENERGY SAVING POTENTIAL GJ/YR	VALUE OF ENERGY $	CAPITAL COST $	OPERATING COST $	SAVINGS $	PAY BACK YEARS
1	1500	4700	20,000	400	4300	4.65
2	1900	5890	39,000	750	5140	7.58
3	1600	4960	18,000	2400	2560	7.0
4	0	0	0	0	0	0
5	1100	3410	14,000	250	3160	4.4
6	0	0	0	0	0	0
7	800	2480	8,000	1100	1380	5.79
8	223,200	692000	2,600,000	52000	640000	4.06
9	20800	88500	240,000	43000	45500	5.3
10	0	0	0	0	0	0
11	600	930	7,000	120	810	8.64
12	0	0	0	0	0	0
13	3200	10,200	23,200	120	10,080	2.3
14	134,800	418000	1,300,000	26000	382000	3.40
15	500	1550	7,000	120	1430	4.9
16	384000	610000	3,300,000	350000	260000	12.69
17	240000	744000	4,600,000	46000	698000	6.59
18	1000	3100	14,000	250	2850	4.91
19	5000	15500	130,000	8250	7250	17.9
20	28000	86800	280,000	53000	33800	8.28
21	2500	7750	90,000	5200	2550	35.3

TABLE D-1 (Cont'd)

ESTABLISHMENT NUMBER	ENERGY SAVING POTENTIAL GJ/YR	VALUE OF ENERGY $	CAPITAL COST $	OPERATING COST $	SAVINGS $	PAY BACK YEARS
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	1950	6820	18,000	2400	4420	4.1
25	4800	35200	120,000	18100	17100	7.0
26	16000	70400	160,000	37000	33400	4.8
27	192000	595200	1,400,000	293000	302200	4.63
28	400000	1240000	3,230,000	85000	1155000	2.80
29	480000	1488000	4,100,000	360000	1128000	3.60
30	12000	7200	150,000	22900	243000	6.2
31	42000	180200	375,000	75900	104300	3.59
32	160000	496000	1,400,000	970000	226000	6.2
33	7500	23520	210,000	4000	19520	10.8
34	0	0	0	0	0	0
	2,366,750	6,842,310	23,853,200	2,457,260	5,333,750	4.41

Canada
Energy, Mines and Resources Canada
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MANITOBA
DEPARTMENT OF ENERGY AND MINES

MG-9979